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The Development of Science Teaching Materials Based on STEM to Increase Science Literacy Ability of Elementary School Students

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ABSTRACT

*The purpose of this research is to develop science-based teaching materials STEM (Science, Technology, Engineering, and Mathematics) to improve science literacy skills of elementary school students. This study uses the Research and Development (*Research and Development), *Procedures studies using models dick and carey which has ten stages, namely:(1)Identifying Learning Objectives; (2)Conducting Instructional Analysis; (3)Analyzing Student Characteristics and Learning Contexts; (4)Formulating Special Learning Objectives; (5)Developing Assessment Instruments; (6) Develop learning strategies; (7) Developing and Selecting Teaching Materials; (8)Carry out formative evaluations; (9) Making a revision of learning; (10)Design and carry out summative evaluation. Data analysis used qualitative descriptive and quantitative descriptive analysis. Design of teaching materials reviewed from the results of expert judgment's. The practicality of teaching materials is viewed from the assessment of the implementation and response of users. The effectiveness of teaching material is seen from the mean of posttest value is greater than the mean of pretest value. The results of this research is (1) STEM-based teaching materials to improve the ability of scientific literacy valid and feasible to use; (2) STEM-based teaching materials are practically used in learning: (3) STEM-based teaching materials are quite effective in improving students' science literacy skills.*

Key Words: Ability, Teaching Materials, STEM, Science Literacy Skills.

1. INTRODUCTION

Science education has an important role in everyday life. Science education encourages students to think in understanding phenomena or natural events by scientific methods. Science education also prepares students to become responsible citizens toward the phenomena around them. Science education is not only limited to the concept, but provides direct experience in the development of product mastery, processes, and attitudes or more widely mastered science literacy. According to the National Research Council, the 21st century is a century where science literacy is the focus of science education.[1] Science literacy deals with various aspects of human life, such as environment, economics, mathematics and other issues related to technological advances and the development of science, therefore, the mastery of science literacy is a necessity for every student.

The measurement of science literacy by PISA in 2012 put Indonesia at the bottom of the list of 64 out of 65 participated countries.[2] While the results of PISA 2015 showed an increase graph of the 72 participated countries. Indonesia ranked 8th from bottom. There is Increase of science competence score from 382 in 2012 to 403 in 2015.[3] Both in 2012 and 2015, the value of science score in Indonesia is still below the average 500 of the value set by PISA, which is only reached Low International Bencmark.

Based on these data, it is clear that the ability of science in Indonesia is still far from expectations. Mastery of science is only limited to material handling and has not been able to relate it to more complex or abstract scientific topics. The low result of

science literacy ability of Indonesian students is caused by several factors. one of them is the teaching materials used. In science learning, the learning process will run more optimal when maximizing all teaching materials that support students. Teaching materials can contain problems in the context of daily life and require students to experiment and present data creatively.

The results of need analysis show that students use interesting teaching materials and use communicative language so that it is easy to understand. The existence of teaching materials in teaching and learning activities is very important for teachers and students. Teachers will have difficulty in improving learning without enough teaching materials, students will also have difficulty in learning. The quality of teaching materials is crucial in an effective learning process. The quality of learning is low when the teacher is only limited to teaching materials that is conventional without containing creativity to develop teaching materials innovatively.

Based on these problems, it is necessary to develop teaching materials that can play a role in the learning process, both in terms of content and approaches that of course can help improve the ability of science literacy students. One of the learning approaches that can be used to train science literacy skills is the STEM learning approach. STEM (Science, Technology, Engineering, and Mathtematics) is an important issue in education today.[4] STEM learning is an integration of science, technology, engineering, and mathematics learning that is suggested to help the success of 21st century skills.[5] STEM can develop when it is linked to the environment, so that becomes a lesson which presents the real world that students experience in daily life.

Teaching materials need to be developed because it can assist teachers in the delivering of materials and achieve learning objectives. Development of teaching materials can facilitate students to achieve the expected competencies. The research results of Onasanya & Omosewo proved that teaching materials are able to help teachers interact with students.[6] It encourages students to use their intellectual abilities during the learning process.

In the learning process there is an interaction among teaching materials, teachers, students, and the learning environment so that it has an impact on improving students' scientific literacy. Teacher's creativity and innovation in classroom management in implementing a learning approach become a way in achieving and developing the students' competence, therefore, teachers are expected to prepare before starting science teaching and learning activities. It starts from developing tools that refer to process standards, content standards and Indicators of Competence Achievement. Students' scientific literacy skills are determined by the learning process that takes place in the classroom with variety backgrounds of family life and student environment. Learning by raising real issues in daily life is packed with STEM approach. STEM is a global movement in educational practice that integrates with various integration patterns to develop the quality of human resources that suits the demands of 21st century skills. STEM-based science learning as one of the forms of STEM education is compatible with current curriculum system in Indonesia. Through the STEM approach, the students not only memorize the concept, but rather the way students understood and understand the concepts of science and its relation in daily life. So that the selection of materials that will be presented in teaching materials that will be developed should be related to daily life. Water Cycle Material is chosen because of the many applications in everyday life related to the material.

Based on that, researchers developed STEM-based science materials to improve the literacy skills of elementary school students. The teaching materials that will be developed in this research encapsulate STEM approach in improving science literacy capability, the teaching materials are developed containing STEM aspects in an integrated way both in terms of science, technology, technique, and mathematics as well as incorporating the balanced aspects of scientific literacy in the presentation of teaching materials. The developed teaching materials are packed using communicative language and the use of colors on the drawing and writing to be interesting and fun to read, as well as the concepts conveyed in teaching materials related to daily life.

2. THEORITICAL STUDY

2.1 Science Education in Elementary School

Science is part of our lives and our lives are part of science learning. Science learning ideally not only learns about the product, but also pay attention to aspects of processes, attitudes, and technology so that students can really understand science as a whole in accordance with the nature of science, therefore in science learning, teachers should prepare a learning experience for students who emphasize on the aspects of the product, its processes, its attitudes, and its relation with daily life.

Usman Samatowa argues that science learning in elementary schools should open the opportunity to nurture students' curiosity naturally.[7] That way, science learning can help students develop the ability to ask questions, find answers to a problem based on evidence, and develop a scientific way of thinking. Culling ford added that science learning should give students the opportunity to develop curious attitudes and logical explanations.[8] This is important so that students are not only given the theory without

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knowing the process of the theory. Thus, students do not just memorize but understand the theory, and the learning can encourage students to express their creativity, develop logical thinking, and the ability to generate scientific explanations.

The main aspect in science learning is that children can realize their limited knowledge, have a high curiosity to gain new knowledge, and apply it in daily life. This must be supported by the growing and increasing curiosity of children, how they review existing information, make decisions, and find the form of application suitable to be applied in their self and society. Thus, science learning in elementary schools is expected to contribute positively in empowering children. So it can be concluded that there are several important aspects that need to be considered by the teacher in learning science in elementary schools, namely teaching materials used, learning resources used and learning processes that is carried out because science learning must be carried out in such a way to provide valuable learning experiences for children .

2.2 STEM

STEM term introduced by the NSF (National Science Foundation) United States in 1990 as an abbreviation for "Science, Technology, Engineering, and Mathematics".[9] STEM refers to the four fields of science, science, technology, engineering and math. According to The United States Department of Education, states that, STEM Education is an educational program with the study of science, technology, engineering and mathematics embedded in its core objectives, in order to Strengthen the education In These subject areas from primary and secondary education through to PhD, as well as adult education.[10]

Learning by using the approach STEM directly trains the students to be able to integrate each of these aspects at once. The learning process which involves four aspects shaping knowledge of the subject studied more understandable. Characters in STEM learning is the ability of learners to recognize a concept or knowledge in a case. As in study Natural Sciences, the STEM helps learners to use technology and assemble an experiment that can prove a legal or scientific concept. The conclusion of this experiment is supported by the data which has been managed mathematically.

STEM learning emphasizes design also focuses on connecting students' scientific ideas across different disciplines. Pearson and Schweingruber state the students involved in learning STEM need support to elicit the relevant scientific or mathematical ideas in an engineering or technological design context, to connect those ideas productively, and to reorganize their own ideas in ways that come to reflect normative, scientific ideas and practices".[11]

Application of STEM approach in learning is of course integrated during the learning process. The four aspects of STEM take part in every implementation of the learning steps. The steps of each implementation are (1) the science aspect is the skill of using knowledge and science process in comprehending natural phenomenon and manipulating the phenomenon so that it can be implemented; (2) technology aspect are the skills of learners in knowing how new technologies can be developed, the skills of using technology, and how technology can be used in facilitating human work; (3) the engineering aspect is person's skill to operate or assemble something; and (4) mathematics aspect is a skill used to analyze, give reason, communicate ideas effectively, solve problems, and interpret solutions based on computation and data mathematically. Based on the exposure, it can be concluded that STEM is an approach that integrates science, technology, engineering, and mathematics in a complete learning without reducing the purpose of its field.

2.3 Teaching Material

The learning process not only talks about learner relationships, but in it related to various elements that support the learning process. One of them is the existence of teaching materials. According to Lewis in Agung mentions that the teaching material is a spectrum of educational materials that teachers use in the classroom to support specific learning objectives, as set out in lesson plan.[7] Dick, Carey, and Carey add that instructional material contain the conten either written, mediated, or facilitated by an instructor that a student as use to achieve the objective also include information thet the learners will use to guide the progress.[12]

Teaching materials are all forms of materials used to assist teachers or instructors in implementing the process of learning in class. The teaching materials contain content that students need to learn either in the form of print or facilitated by the teacher to accomplish certain goals. Raquel add statements teaching materials can make teaching complexities become simple.[9] Good teaching materials are teaching materials that can be used and help students in the learning process. For that, teaching materials should be prepared based on the needs of learners. The need for teaching materials is determined by the environment, the development of information technology, and the culture of society in which education takes place.

Based on the understanding, it can be concluded that the teaching materials are all materials (both information, tools and text) arranged systematically, presented thoroughly from the competence to be mastered by students and teaching materials are also used in the learning process with the purpose of planning and implementation of learning. Teaching materials is a material that continues to grow dynamically in line with the progress and demands of the development of society, teaching materials received learners must be able to respond to every change and anticipate any future developments, therefore teaching materials is a core element that is in Learning Activities.

Teaching materials in the learning process occupies a very important position, because the teaching material is the material to be delivered or presented. Learning will not be realized without the teaching material. Teaching materials are the core of the curriculum that serves as a means of achieving goals in the learning process. The more complete the teaching materials are collected and the broader the insight and the teacher's understanding of the material will be better.

Based on the above theoretical studies the researcher concludes that STEM-based science material is a teaching material used in science lesson that integrates science, technology, engineering and mathematics in one science lesson, by developing science as concept and process, technology as application of science, engineering as a science engineering, and mathematics as a tool in scientific proof.

2.4 Scientific Literacy Skills

The use of the word literacy originally refers to the ability to read, write and count. But with the rapid development of science, the term began to develop. Viorel Dragos, science literacy describes the ability of an individual to understand scientific laws, theories, phenomena and things. This means the responsibility of each citizen to have the necessary scientific knowledge base to make practically any informed decision of his life. [15] Meanwhile The U.S National Center for Education Statistics describes scientific literacy as perceiving and understanding scientific concepts and processes which the citizen needs to make decisions and participate in civil and cultural affairs and economic production rates.[16] Understanding above emphasizes the use of science literacy in helping perceive and understand the scientific concepts and processes that a person needs. It helps in making decisions and participates in civil, cultural and economic affairs.

Another opinion on science literacy is expressed by Holbrook & Rannikmäe that defines science literacy in a broad sense, that is, as the development of creative ability to utilize appropriate knowledge-based scientific and skill evidence, especially with relevance for daily life, solving scientific problems personally but meaningful and responsible decisions.[17] Whereas for understanding is specifically explained by Toharudin et al., Who conclude science literacy as a person's ability to understand, communicate, implement, solve problems of scientific knowledge so that they have a sensitive attitude towards themselves and their environment in making decisions based on science.[18]

Thus it can be concluded that scientific literacy is a person's ability to understand science and apply it in daily life to solve problems that arise so that they have a high sensitivity to themselves and their environment in making decisions based on consideration of scientific considerations. Literacy ability for elementary school students is very important because it affects the success of learning in school and life later in the community. Students who have high literacy skills are usually more capable, independent, and easy to follow developments in science and technology, the existence of scientific literacy skills can help develop students' thinking skills and scientific attitudes.

PISA establishes three major dimensions of science literacy in its measurements, namely the process of science, the content of science, and the context of the application of science. The process of science refers to the mental processes involved when answering a question or solving a problem, such as identifying and interpreting evidence and explaining conclusions. These include the types of questions that science can and can not answer, recognize what evidence is required in a science investigation, and recognize conclusions that are consistent with the available evidence. Science content refers to key concepts necessary to understand natural phenomena and changes made to nature through human activity. PISA does not specifically limit the scope of science content only to the knowledge that is the subject of school science curriculum, but this knowledge can also be sourced from other sources. The context of science refers to situations in everyday life that are landed for the application of processes and understanding of the concept of science.

Based on the explanation, the researcher concludes that science literacy assessment is not only oriented to the mastery of science material but also on the mastery of life skill, ability to think and ability in conducting real-life science process, and in essence science literacy covers lifelong learning competence and the competence of using knowledge to meet the needs of life that is influenced by the development of science and technology.

Assessment of scientific literacy capability in accordance with PISA researchers developed in the following table of science literacy indicators:

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Table 2. 1. Indicators for Science Literacy Skills

No.	Aspect	Indicators
1.	The Process of Science	Identify scientific questions, explain phenomena scientifically and use scientific evidence.
2.	The Content of Science	Describes natural phenomena and changes made to nature through human activity.
3.	The Context of The Application of Science	Application of science knowledge and science poses in everyday life.

3. STUDY METHEDOLGY

The Methods in this study use research and development. The purpose of this study is to produce teaching material based on STEM on teaching natural science that is valid, practical and has potential effect in order to improving students' science literacy ability. The Procedures of studies use Dick and Carey's model which has ten stages, that are: (1) Identifying Learning Objectives; (2) Conducting Instructional Analysis; (3) Analyzing Student Characteristics and Learning Contexts; (4) Formulating Special Learning Objectives; (5) Developing Assessment Instruments; (6) Develop learning strategies; (7) Developing and Selecting Teaching Materials; (8) Carry out formative evaluations; (9) Making a revision of learning; (10) Design and carry out summative evaluation.

The subjects of this research are the students of grade V State Elementary School Babakan Turi Cilegon, Indonesia. There are 35 respondents where in the Small Group Try-Out trial phase is 10 respondents and in the Field Try-out trial phase is 25 respondents. The data used are qualitative data and quantitative data with Instruments used are questionnaire and test. Qualitative data were obtained from requirement analysis, expert material test questionnaire, expert language test, and expert presentation test. Meanwhile, the quantitative data is obtained from the product trial, that is the field test. The research design used is one group pretest post test design. In this design, before the treatment is given in advance the students are given pre test and at the end of the learning students are given posttest. This design is used to determine the effectiveness of the product made.

4. RESULT AND DISCUSSION

The products that are successfully developed in this study is science teaching materials based on STEM that are valid, practical, and has a potential effect in improving students science literacy skills. The product is packaged in printed form and used as a support in the learning process. The products that are produce are in the form of teaching materials that contain the concept of natural science which is integrated with the concepts of science, technology, engineering, and mathematics in a single science concept, in which science as a process, technology as the application of science, technique as a science, engineering and mathematics as a scientific proof.

The contents of STEM-based teaching materials are developed, divided into four parts, that are introduction, core, cover and complementary. The introductory section consists of Title Page, Preface, Introduction, the use of Teaching Material Instructions, Contents, Core Competencies, Basic Competencies, and Learning Indicators. The core consists of three lessons, Lesson 1 contains three sub-topics: the Water Cycle, Human Activity Affecting the Water Cycle, and the Ground Water Cycle. Lesson 2 contains three sub-subjects: Clean Water, Water for daily Needs, and filtering Process and Water Purification. And Lesson 3 contains two sub-topics: Water Saving, and Water Saving Action. The concluding section consists of a Material Summary, Final Learning Evaluation, and Bibliography. As well as a complementary section consisting of Science Info and the Science Dictionary which is located in each learning.

The validity of teaching materials based on STEM is seen in terms of material (suitability of material with the science concept, conformity of material with development characteristics and needs of elementary school students), aspects of language (the use of grammar that is more effective and communicative), and aspects teaching materials presentation (display of teaching materials are interesting and easy to use). Validation is carried out by a team of experts, a team of experts that is involved namely science material experts, linguists and experts in the presentation of teaching materials. The assessment results of the validation by the material experts can be seen in the table below:

Table 4.1. Result of Assesment by Expert Material

No.	Aspect	Total score
1.	Suitability of the material with KD and Indicator	8
2.	The accuracy and truth concept	12
3.	Support learning material	8
4.	Sequence and systematics dish concept	18
5.	Completeness of the presentation of the material	18
Percentage Score and caption: $\frac{score\ of\ acquisition}{score\ of\ the\ maximum\ (75)} x100\%$		85.33% (Very Good)

Expert material validation result gets the average score of the overall indicator aspect is 85.33%. This score indicates that the teaching materials developed from the material presented is scored "Very Good". So it can be said that the development of STEM-based teaching materials in science is worthy from from the assessment of material experts. Furthermore linguists validation results can be seen in the table below:

Table 4.2. Results of Assessment Language

No.	Aspect	Total score
1.	Proficiency learners	8
2.	Language rules	21
3.	Choice of words	5
4.	Communicative language style	19
Percentage Score and caption: $\frac{score\ of\ acquisition}{score\ of\ the\ maximum\ (60)} x100\%$		88.33% (Very Good)

Validation results of linguists are obtained an average score of all indicator aspects is 88.33%. This score indicates that the teaching materials developed in terms of language was scored "Very Good"so it can be said that the development of STEM-based teaching materials in science subjects is worthy from the assessment of linguists. Furthermore, the results of expert validation presentation can be seen in the table below:

Table 4.3. Result of Assessment by Expert Presentation

No.	Aspect	Total score
1.	Display desaian / Layout layout	9
2.	The contents of the text / typography	8
3.	Animation on the book	10
4.	The illustrations in the text	9
5.	Suitability color selection	10
6.	The use of the font size	8
7.	The accuracy of image placement	8
Percentage Score and caption: $\frac{score\ of\ acquisition}{score\ of\ the\ maximum\ (70)} x100\%$		88.57% (Very Good)

The validity results of the presentation are obtained an average score of all of the aspects that is 88.57%. This score indicates that the teaching materials developed in terms of the presentation was scored "Very Good", so it can be said that the development of STEM-based teaching materials in science subjects are worthy from material assessment experts..

While for the practicality of teaching materials based on STEM, it can be said that it is practical by looking at the results from small group evaluation and field evaluation. Based on the analysis of students' answers on teaching materials, most of students can complete every stage that is on the teaching materials well. In addition, the students' comments also state that the teaching materials given are easy done by students. The following test results of Small Group evaluation can be seen in the table below:

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Table 4.4. Small Group Evaluation

No.	Aspect	The Average Score	Interpretation
1.	Like	89.78%	Very Good
2.	Comprehension	89.33%	Very Good
3.	Teaching Material Display	92%	Very Good
On average Overall		90.37%	Very Good

Based on the results of the Small Group evaluation carried out on 10 students, it is obtained results with an average for aspects of love have a value of 89.78% with the criteria "very good", on the aspect of comprehension has an average value of 89.33% with criteria "very good". In the aspect of appearance, teaching materials have an average value of 92% with the criteria of "very good". So that the final practicality score for STEM-based teaching materials is 90.37%. it can be said that STEM-based teaching materials are practical and easy to use in science learning. Field evaluation conducted to 25 students, the results of this trial are presented in the table below:

Table 4.5. Field Evaluation

No.	Aspect	The average score	Interpretation
1.	Like	90.56%	Very good
2.	Comprehension	90.56%	Very good
3.	Teaching Material Display	91.36%	Very good
On average Overall		90.83%	Very good

The test result of Test Field evaluation is obtained results with the average to aspects of love value of 90.56% with the criteria "very good", in the aspect of comprehension gets a value of 90.56% with the criteria "very good", in the aspect of teaching materials display acquires a value of 91, 36% with the criteria of "very good". So the final score of practicality of STEM-based teaching materials is 90.83% can be said that based on field evaluation result of STEM-based teaching materials that is practical and easy to use in learning science.

Furthermore, to look at the effectiveness of teaching materials in improving science literacy can be seen from comparison of the results of students' pretest and posttest. The following comparison of pretest and posttest results are presented in the diagram below:

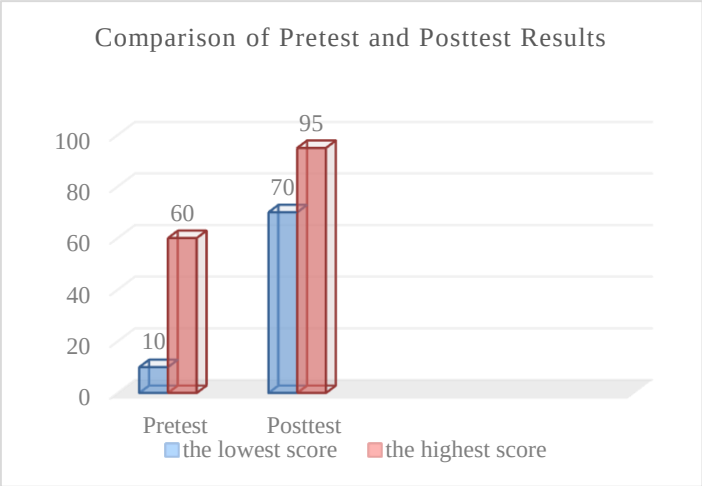

Figure 4.1. Comparison of Pretest and Posttest Results

Based on the comparison of pretest and posttest score, there is a significant comparison, before using STEM-based science materials, the highest score does not reach the minimum completeness criteria, with a minimum mastery criterion of 70. Whereas after using STEM-based science materials the highest score reaches the minimum mastery criteria. This shows that the use of STEM-based science teaching materials can improve scientific literacy skills in terms of learning outcomes. Thus the product of STEM-based science teaching materials that researchers develop has the effectiveness to improve the ability of science literacy in science learning activities in grade V elementary school.

5. CONCLUSSION

Based on the research and development stages are passed, the conclusions of this research are as follows:

a. This study has produced STEM-based science materials that are classified as valid, practical and have effectiveness in improving the ability of science literacy. Validity of teaching materials is based on material, language and display. In terms of material, STEM-based teaching materials that researchers developed have been in accordance with KI and KD in the curriculum 2013 and in accordance with the natural science concept. In terms of language, the instructional material developed has been in accordance with Enhanced Spelling (EYD), the formulation of communicative sentences, using simple, non-ambiguous and easy to understand. Whereas in terms of presentation or display, STEM-based teaching materials is interesting and loved by the children. After the tested try to learners of science materials based on STEM is either individually or small groups and the field provides high practical value with easy to use and provide ease in understanding the material.

b. This STEM-based science teaching material, both in small groups and in the field, gives high practicality values with easiness of use and gives easiness in understanding the material.

c. The use of STEM-based teaching materials in science learning provides effectiveness in improving scientific literacy skills, this can be seen from the results of the pretest and posttest which showed a significant increase.

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